Online ISSN: 2367-5357
DOI: 10.7546/itc-2019-0009

Personal Assistant Architecture in Virtual Educational Space

Y. Todorov, I. Popchev, I. Radeva

Key Words: *Virtual educational space, personal assistant, referential architecture, BDI.*

Abstract. *The article presents a reference architecture that will be applied by each assistant in the Virtual Educational Space and two assistants – LISSA and BLISS based on the reference architecture.*

1. Introduction

With the development of technology and the easier access to information nowadays, we witness the appearance of a new group of people, who crave knowledge and constant access to a new information and notions. This group of people is growing rapidly, so the need for permanent access to information has become a set standard. To satisfy the occurring requirements for knowledge, the concentrated development of intelligent assistants in everyday life has begun. These assistants aim to grant the user with more comfortable access to information or service.

Such development led to the elaboration and integration of a system, which is going to assist education in schools and universities. Two major types of systems were defined, and they are widely used up even today. Learning Management System, which allows electronic education in the form of different courses, as well as following the progress of the student, but does not support the creation of original content. Also, the second type – Learning Content Management Systems, which supports the creation and access to original content by using centralized storage.

Researching the matter further, in the Plovdiv University were defined a third type – Distributed eLearning Center (DeLC) [16, 17], which allows decentralization of the content. Considering how the functionalities of DeLC are growing, as well as the need for a more flexible system, which will allow even more functions, the development of Virtual Educational Space (VES) [5, 20] was imminent. VES integrates the functions of DeLC in itself, but at the same time offers a vast number of additional services, all that possible because of the many intelligent components that the VES system is built upon. An essential part of VES is the number of personal assistants, which ensure users' easy access to space and the services that the system provides, regardless of their current location. In this article is present referential architecture, which is going to be the basis of all personal assistants in the space.

2. Related work

The development of personal assistants, drastically increased its pace in the last few years. Nowadays, almost each bigger company owns or develops a personal assistant for their clients and employees to use. The personal assistants, which are being used and developed, can be divided into two main groups:

A) Assistants for mass use: These are assistants, which are intended for the mass client and which offer general functionalities. Under this group, there are assistants such as:

- **Siri** [15] – One of the first and maybe the best-known personal assistants. Apple develops it, and its purpose is to answer the questions, which the user asks. To do that, it searches for the question on the Internet and returns the answer by using its text to speech library.
- **Google Now** [8], **LG Voice Mate** [4], **Cortana** [9] – These assistants are similar to Siri in their functions but are developed by other famous companies (Google, Amazon, Microsoft). Each of the four companies is continually improving the functionality and skills of their assistants.

2) Specialized assistants: These are assistants, which are specialized to help the users in specific fields. Under this group, there are assistants such as:

- **Irma** [11] – An assistant specialized to help in the movement of his users, by using different sources of information to offer suitable services.

• **CAP** [10] – CAP is designed to help users, by following events and efficiently managing schedules and updating them.

• **Virtual Assistant Guiding Students for College applications** [12] – An experimental assistant created by facilitating an application at Georgia State University, assisting prospective students by providing them with information about the required document and reminding them of essential approaching dates. Thanks to the assistant, a 3.3 % increase in successful enrollment students have been established.

• **HealthPal** [7] – HealthPal is a healthcare assistant, enabling the monitoring of the vital signs of the user.

3. What is VES

VES is a Virtual Education Space built as the Internet of Things Ecosystem, with the primary purpose of supporting the learning process, by providing a set of services for both students and lecturers.

VES has context-awareness and can detect and identify changes as soon as they occur. It is built by independent components each of which has a specialized task. Irrespective of external factors and subject to change regarding the type of training and the user's needs. The most important feature of the space is its ability to make decisions when necessary.

For spatial purposes it has been built an Event Model [6] that is used by all the components in the space. In fact, the whole space is event-oriented and almost every action is a reaction to an event or the creation of a new one.

The Event Mode is defined four major types of events:

1) *System events*: Linked with changes in the space.
2) *Domain events*: Applicable only for the domain in use.
3) *Basic events*: All activities that do not need additional features.
4) *Emergency events*: High-priority events responding to an emerging danger, that directly involves the users.

4. The referential architecture of VES personal assistant

There is a scheme of the referential architecture of an assistant, which is shown in *figure 1*. This architecture is supposed to be used by all BDI [14] agents of the space and is divided into three layers.

The first layer is called the "**receiver layer**". Its purpose is to hold the sources of incoming information. Currently, there are two interfaces inside of it:

• **Agent to Sensors communication interface –** It serves to take in and process the information coming from the sensors of the local device, e.g., location, time, date, etc.

• **Agent to Software communication interface –** It is used for incoming information, from foreign none agent systems. Communication is usually done with the RestFul service. The incoming information is used as Belief in some cases, and in others is transferred to a standard ACL [1] message it is then sent to the Logical Core, which processes it and decides what to do with it.

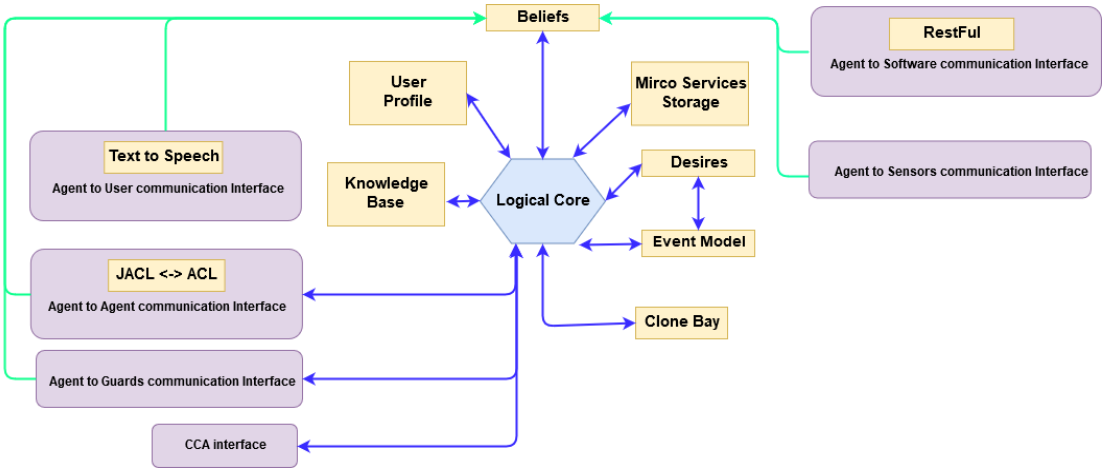

Figure 1. Referential architecture of PA in VES

The second layer is called the "**communication layer**". It allows the procession of both incoming, and outgoing information. For now, it has four components:

- **CCA interface** [3] – It ensures connection to the CCA. It is used when ambient information is needed. For example, when a disabled student needs to reach a specific classroom, CCA is going to be asked to find a suitable route with ramps, which is going to be of use to the student.

- **Agent to Guards communication interface** – It helps the personal assistant to communicate with the Guards of the space. This type of communication is critical, because thanks to it, the PA gets warnings from an agent when something of great importance occurs. For example, when there is a natural disaster or the room needs to be evacuated. The information is transferred to the Logical Core, which processes it and decides how to react, based on how it is affecting the current user.

- **Agent to Agent communication interface** – It serves for communication between the rest of the assistants and agents in the space. Communication often happens between two JADE [2] agents via ACL messages, which correspond to the FIPA standard. Since space also includes JADEX [13] agents, which by default do not support ACL, there is a built-in translator between ACL and JCAL in the interface. The latter has a specific library that is incorporated explicitly in order to be able to communicate with JADEX agents, without needing to stray from the FIPA standard.

- **Agent to User communication interface** – serves for two-way communication between the user and the assistant. Communication could either happen in the standard way – by the user pressing on the display and the assistant visualizing information on the screen. Alternatively, by voice commands, exchanged by both participants, with the help of Google's Text to Speech library.

The third layer is called the "**middle layer**", and it contains all of the internal components, as well as the logical core of the assistant:

- **Beliefs –** contains information regarding the environment, which is divided into two levels: the first level is called "standard beliefs" (time, date, location), which are used by all assistants with BDI architecture; the second level is called "profiled beliefs", which are oriented towards a specific profile and type of the assistant.

- **User profile –** contains information regarding the user, which is used when making decisions and updating the desires, based on changes in the environment.

- **Knowledge base –** contains all of the knowledge of the assistant. It is divided into three levels. Default sets the first level of knowledge, at the moment the assistant is created, and it is called "primal knowledge". The second level is acquired after communication with a particular user and is used when making decisions with the right approach for the said user. It is called "personal knowledge". Knowledge, which is acquired by analysis of plenty of personal knowledge, is called "global knowledge" and is used by all instances of the personal assistants to make decisions, all that allows a constant system self-upgrade.

- **Micro services storage –** contains all the services, which the personal assistant provides.

- **Desires –** contains all desires of the assistant, and for their correct definition, the rules of the Event Model are used.

- **Event model –** contains rules for the model of events and a list of different event types. It is used when defining desires, as well as setting up an intention, and creating a plan for action.

- **Logical core –** contains the entire logic of the personal assistant. This is the brain of the agent and the place where decisions are made when the environment allows the fulfilling of the desires. Here, it is decided what will happen to all of the information, incoming from the other two layers of the assistant and with the logic for self-teaching and updating the knowledge base.

- **Clone bay –** if the PA needs to complete many tasks at the same time and wants to prevent any losses, it can clone itself by creating a restricted clone for a specific task. The clone only has parts of the architecture of the chief assistant, and they depend solely on the task at hand. It starts working on the task from the moment it is created. When the task has been finished, it sends a report of the actions taken and the acquired knowledge to the original agent, after which it self-deletes and stops existing. Currently, there are not any limitations about the number of clones, which can exist at the same time.

5. Implementations of referential architecture

Up to the present moment, two elaborations were implemented, which are based on the referential architecture described above. The first implementation is named Learning Intelligent System for Student Assistance (LISSA) [18, 19]. Its purpose is to be used by the students of Plovdiv University. The second implementation is oriented towards the Independent study students in the Secondary school of Brezovo and is named Brezovo's Learning Interactive School System (BLISS).

A. LISSA

LISSA's purpose is to be of help to the study process of the students in the Math and Informatics Faculty of Plovdiv University. The assistant went through different stages of development, and its architecture has been

changed many times. As for now, it was settled for the following referential architecture.

There is the life cycle of LISSA, shown on *figure 2*. It is divided into four phases.

Registration is the first phase of the life cycle and serves to create the student's profile. A series of questions are generated, and the student answers the questions accordingly. Their profile is created on the base of their answers.

Initialization is the phase, in which the assistant creates the student's calendar with all upcoming events for that student, once it has been started. In case that the student already has a calendar ready, a copy of it is going to be sent to them. All events in the calendar are part of the "desires" base of the assistant.

```
/* Registration */
B0 ← get_percept;
while need_information(Q0, A0) do
    AΣ ← ask_question;
end-while
profile ← register(AΣ, student_id);
/* Initialization */
Desires ← create_PC(profile, B0);
B ← B0;
I ← I0;
/* Deliberation */
while true do
    percept ← get_percept;
    B ← update(B, percept);
    ε ← calculateInterval(Desires);
    D ← identify_goal(ε, B, Desires);
    I ← compose_goal(B, D, I);
    /* Planning */
    π ← plan(B, I, Ac);
    while not (empty(π) or succeeded(I, B) or impossible(I, B))
do
        α ← head(π); execute(α); π ← tail(π);
        percept ← get_percept;
        B ← update(B, percept);
            if reconsider(I, B) then
               Desires ← update(B, I, Desires);
               if needed then update(profile);
               break;
            end-if
    end-while
end-while
```

Figure 2. LISSA's life cycle

Deliberation phase is the phase for the agent's routine work. Through this phase, it is looking for changes in the environment, and when the conditions are right to fulfill a specific desire, it starts to transition to the **planning phase**. It is important to point out here, that the interval ε is used to determine an event, for which the user is going to be notified.

ε is of enormous significance in the life cycle of the assistant because it can be a cause of a deviation from the standard Event Model, which the VES space is using. To avoid any diversions on the model, this interval is used as an early warning, as the values of ε vary, depending on the events. In the figure above is shown the moment, in which the interval is set according to the current **desires** **ε ← calculateInterval** (**Desires**). The earliest warning is always prioritized.

The planning phase is used to create a plan for action and execute it. While executing a more extended plan, for example when navigating a wheelchair on a precise route, the information about the environment is continually being updated, and appropriate action is taken in need.

As it was already mentioned, the goal of the assistant is to help students by assuring their access to the virtual studying space, regardless of their current location. The personal assistant offers the following functions to its user:

1) *A reminder of upcoming events*: The assistant reminds the user of an exam, a lecture, etc., which is coming shortly. Depending on the type of the event, the period of the notice can vary. For example, if there is an upcoming exam, the assistant gives a notice two weeks before the event and keeps reminding every day, so that the student has the time needed to prepare. For an upcoming lecture, however, the assistant reminds only once, two days before the event.

2) *Offers recommended literature to the student*: The assistant offers the student literature, based on their interests and upcoming exams and lectures. The literature is introduced in the form of links to electronic textbooks in the web, which the student can access via their username and password.

3) *Keeps track of the student's attendance*: Whenever the student visits a lecture, an exam, or another event, the agent automatically notes their attendance.

4) *Navigation to a specific event*: It shows the location of the event and points a route to it in Google Maps.

Apart from the general functions mentioned above, the assistant can offer different profiles. Each different profile is equipped with different hardware sensors that allow the assistant to expand its functionality, to maximize its usefulness. Currently, the following profiles are being supported:

Standard profile – this is the standard profile, which allows only the functions, which are stated above.

Handicap profile – this profile is oriented towards people, who are partially or fully immobile. Except for the standard functions, this one offers partial or full control over the wheelchair via voice commands. When it determines a route from one place to another, with the help of the CCA interface, the agent picks a route, which is suitable for wheelchairs and notes the existence of platforms and ramps and the condition they are in. This sort of information is actualized and updates regularly.

Visually impaired profile – it is used by people with decreased or entirely lost eyesight. To be of use to these people, it uses a camera and OCR libraries, which help them orientate in the environment. It can show the direction to users, who are disorientated and read signs and signboards out loud. One of the existing functions is the ability to read textbooks and reference books to the student.

Hearing impaired profile – it is intended for people with problems with their hearing apparatus. Like the other profiles, this one comes with a few specialized sensors. In this case, there are a couple of sensitive microphones, which are trying to create a "map" of each of the sounds, surrounding the user and to inform them of different events. Informing the student happens with the help of vibration of the device. There are different types and degrees of vibration, depending on the type of the event. For example, when a danger from behind is detected, the personal assistant is going to start vibrating with maximum intensity, to warn the user of the situation. When the assistant detects the student's name with one of the microphones, it will vibrate lightly three times, to warn them that somebody has said their name, etc. Except for the warnings, the assistant writes down all conversations and shows them to the student in the form of a text. This is going to prove extremely useful during a lecture, which is not accorded to the student's needs.

Currently, it has been developed a prototype of the standard profile, its start screen is on *figure 3*.

B. BLISS

After the short discussion of the problems that the teachers in the Middle school of Brezovo are facing, it has been decided to develop a multi-agent system, named BLISS. It consists of two personal assistants – the first one is oriented towards the students and the other one – towards the teachers.

The main problem that the system will have to solve is the problematic communication between teachers and students, because of the Independent study practice. The students decide themselves when and how to study, and in case they need help from a teacher, they visit consultations. They also go to final exams so that they can graduate successfully. It was decided to develop a personal system, which consists of two different personal assistants, to ease that process. The assistants have the following functions:

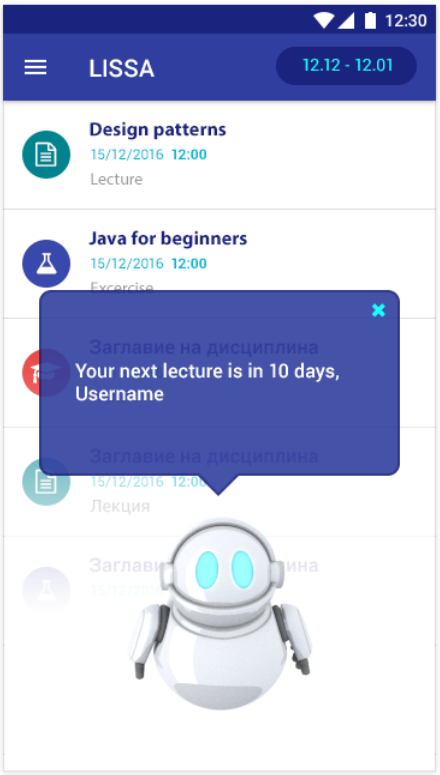

Figure 3. A prototype of LISSA's standard profile

1) *Student Helper* (*SH*): The goal of the assistant is to keep the student informed about everything related to the study process, including any changes in it. This includes notifying about upcoming exams, showing a timetable of the consultations for the disciplines, which they have to visit, and also possible encouraging of the student to visit these consultations, based on their grades from the previous exam session.

2) *Teacher Helper* (*TH*): The teacher's assistant has a goal to help the teachers follow the progress and communicate with their students. It allows them to send messages to a single student or a group of students, to create new events (such as an extra exam, lecture, lesson, etc.) for particular student or group of students, to send materials for different study disciplines, to finish personal reports and registers, which are mandatory for each student.

6. Conclusion

This paper described the initial idea and latest development of a student assistant. In the process, it expanded to a significant part of VES, and this contributed to the creation of reference architecture and the development of other assistants. Soon, it is plan to develop prototypes for each of the LISSA profiles and BLISS

assistants listed used by real users. This is an opportunity for testing the prototypes in a real environment.

Acknowledgments

The research is partly supported by the MES by the Grant No. D01-221/03.12.2018 for NCDSC – part of the Bulgarian National Roadmap on RIs.

References

1. Agent Communication Language Specifications, available at http://www.fipa.org/repository/aclspecs.html, last accessed 2020/05/20.
2. Bellifemine, F. L., G. Caire, D. Greenwood. Developing Multi-Agent Systems with JADE, Wiley, 2007.
3. Glushkova, T., S. Stoyanov, I. Popchev, S. Cheresharov, Ambient-Oriented Modeling in a Virtual Educational Space. – *Comptes rendus de l'Acad´emie bulgare des Sciences*, 71, 2018, 3, 398–406.
4. Google Now web page, available at http://www.digitaltrends.com/mobile/how-to-use-google-now/, last accessed 2020/05/20.
5. Gramatova, K., S. Stoyanov, I. Popchev, Virtual Education Space Realization as an Internet of Things Ecosystem. – *Engineering sciences*, LV, 2018, 1/2018, 5–19.
6. Guglev, Z., S. Stoyanov. Hybrid Approach for Manipulation of Events in the Virtual Referent Space. Proceedings of the International Scientific Conference Blue Economy and Blue Development, 1-2 June, 2018, BFU, Burgas, 197–203.
7. Komninos, A., S. Stamou. HealthPal: An Intelligent Personal Medical Assistant for Supporting the Self-monitoring of Healthcare in the Ageing Society. Proceedings of the 4th International Workshop Ubiquitous Compututing for Pervasive Healthcare Application, Sept. 17–21, 2006, https://pdfs.semanticscholar.org/7e9d/ba3773fc81556418543354fe8065e8cf8ef8.pdf.
8. LG voice mate webpage, available at http://www.lg.com/us/mobile-phones/VS985/Userguide/388.html, last accessed 2020/05/20.
9. Microsoft Cortana web page, available at https://www.microsoft.com/en-us/cloud-platform/cortana-intelligence-suite, last accessed 2020/05/20.
10. Mitchell, T., R. Caruana, D. Freitag, J. McDermott, D. Zabowski. Experience with a Learning Personal Assistant. – *Communications of the ACM*, 37, 1997, 7, 80–91.
11. Motta, G., D. Sacco, T. Ma, L. You, K. Liu. Personal Mobility Service System in Urban Areas: the IRMA Project. Proceedings of the 2015 IEEE Symposium on Service-Oriented System Engineering (SOSE), 30 March – 3 April 2015, San Francisco, CA, USA, 88–97.
12. Page, L. C., H. Gehlbach. How an Artificially Intelligent Virtual Assistant Helps Students Navigate the Road to College, – *AERA Open*, 3, 2017, 4, 1–12, https://doi.org/10.1177/2332858417749220.
13. Pokahr, A., L. Braubach, W. Lamersdorf. Jadex: Implementing a BDI-Infrastructure for JADE Agents. – *Search of Innovation* (Special Issue on JADE), 3, 2003, 3, 76–85.
14. Rao, A. S., M. Georgeff. BDI Agents: from Theory to Practice. Proceedings of the 1st International Conference on Multi-Agent Systems, San Francisco, CA, 1995, 312–319.
15. Siri web page, available at http://www.apple.com/ios/siri/, last accessed 2020/05/20.
16. Stoyanov, S. Context-Aware and Adaptable eLearning Systems. PhD Thesis, STRL, De Montfort University, Leicester, UK, 2012.
17. Stoyanov, S., I. Popchev, E. Doychev, D. Mitev, V. Valkanov, A. Stoyanova-Doycheva. I. Minov. DELC Educational Portal. – *Cybernetics and Information Technologies*, 10, 2010, 3, 49–69.
18. Todorov J., S. Stoyanov, V. Valkanov, B. Daskalov, I. Popchev. Learning Intelligent System for Student Assistance – LISSA, Proceedings of the 2016 IEEE 8th International Conference on Intelligent Systems – IS 2016, Sofia, September 4-6, 2016, 753–757.
19. Todorov, J., V. Valkanov, S. Stoyanov, B. Daskalov, I. Popchev, D. Orozova. Personal Assistants in Virtual Education Space. In: Practical Issues of Intelligent Innovations, Sgurev V. et al. (Eds.), Vol. 140, 2018, 131–153.
20. Valkanov, V., S. Stoyanov, V. Valkanova, Building a Virtual Education Space. Proceedings of the 19th World Multi-Conference on Systemics, Cybernetics and Informatics: WMSCI 2015, Orlando, Florida, USA, 2015.

Manuscript received on 05.02.2019

*Assistant Professor **Jordan Todorov** is a Member of Bulgarian Society of Automatics and Informatics. He received his M.Sc. degree in "Software Technologies" from the University of Plovdiv "Paisii Hilendarski". Currently, he is a Ph.D. student in the field of intelligent personal assistants in the Plovdiv University "Paisii Hilendaski", Bulgaria, where he also works as an Assistant Professor. His research interests include: intelligent agents, agent- and service-oriented architectures, IoT and personal assistants. He has published 11 publication.*

Contacts:
Department of Intelligent Systems
Institute of Information and Communication Technologies
Bulgarian Academy of Sciences
Sofia, Bulgaria
Department of Computer Systems
University of Plovdiv
Plovdiv, Bulgaria
e-mail: jtodorov@uni-plovdiv.bg

Ivan Popchev *since 2003 is a member of Bulgarian Academy of Sciences. He received Ph.D. degree in 1967, with a thesis "Studies on the performance index of large scale control systems" and D.Sc. in 1980, with a thesis "Multicriterial synthesis of control systems". He has more than 480 papers presented at world congresses, conferences, symposia and workshops and/or published in international journal/periodicals, proceedings and books in English, German, French, Russian, Korean and Bulgarian. His research interests are in the fields of computer science, mathematical modelling, decision sciences and control theory.*

Contacts:
Institute of Information and Communication Technologies
Bulgarian Academy of Sciences
Sofia, Bulgaria
e-mail: ipopchev@iit.bas.bg

Irina Radeva *is an Associate Professor at the Department of Intelligent systems of Institute of Information and Commutation Technologies – Bulgarian Academy of Sciences. She received her Ph.D. degree in Informatics 2012 with a thesis "Decision making models for Clusters design". Her current research interests are in decision sciences, multi- criteria analysis and optimization, intelligent systems, fuzzy sets theory and intercriteria analysis applications, economic clustering, intelligent systems and optimization, risk management and control.*

Contacts:
Department of Intelligent Systems
Institute of Information and Communication Technologies
Bulgarian Academy of Sciences
Sofia, Bulgaria
e-mail: iradeva@iit.bas.bg